DOCUMENT RESUME

ED 421 985 IR 018 963

AUTHOR Umbach, Kenneth W.
TITLE Computer Technology in California K-12 Schools: Uses, Best Practices, and Policy Implications.
INSTITUTION California State Library, Sacramento. California Research Bureau.
REPORT NO CRB-98-003
PUB DATE 1998-03-00
NOTE 36p.
PUB TYPE Reports - Research (143)
EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS *Computer Assisted Instruction; *Computer Uses in Education; Educational Development; *Educational Policy; *Educational Practices; Educational Technology; Elementary Secondary Education; Internet; Program Development; *Public Schools; Staff Development
IDENTIFIERS *Access to Technology; *California

ABSTRACT

Computers and Internet access are becoming increasingly frequent tools and resources in California's K-12 schools. Discussions with teachers and other education personnel and a review of published documents and other sources show the range of uses found in California classrooms, suggest what are the best practices with respect to computer technology, and lead to some policy issues for consideration. While not all uses of computer technology found in the schools are necessarily frequent, many different uses have found a place in at least some schools. Some "best practices" are coming to be recognized with respect to computer technology in the schools. Some of these practices are fundamental--planning, staff development, curriculum integration, use of library media centers, professional communications, and use of a "train the trainers" model, among others. Some other practices, such as creation of school Web sites and use of multimedia presentations, are useful tools that are facilitated by the more fundamental practices. Policy implications of computer use are wide-ranging. They include the importance of encouraging planning, the role of funding for the long term, the importance of accounting for staffing needs, and the need to fully address staff development. This paper outlines each of these topics--uses, best practices, and policy implementation--and supplements the discussion with related statistics, a list of selected educational Web sites, a brief description of the important concept of information literacy, and a list of sources and further reading. (AEF)

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COMPUTER TECHNOLOGY IN CALIFORNIA K-12 SCHOOLS:
USES, BEST PRACTICES, AND POLICY IMPLICATIONS

Prepared at the request of
Assembly Member Kerry Mazzoni

By

Kenneth W. Umbach, Ph.D.

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DIGEST

Computers and Internet access are becoming increasingly frequent tools and resources in California's kindergarten through 12th grade (K-12) schools. Discussions with teachers and other education personnel and a review of published documents and other sources show the range of uses found in California classrooms, suggest what are the best practices with respect to computer technology, and lead to some policy issues for consideration.

While not all uses of computer technology found in the schools are necessarily frequent, many different uses have found a place in at least some schools. Examples include long-established (as much as two decades) drill-and-practice types of applications and teaching of typical software applications such as word processing and spreadsheets. Today's uses also include a role for the computer as a lesson-presentation device, as a tool for students to develop multi-media reports, as a research and reference aid, and as a communications tool locally, nationally, and internationally.

Some "best practices" are coming to be recognized with respect to computer technology in the schools. Some of these practices are fundamental -- planning, staff development, curriculum integration, use of library media centers, professional communications, and the use of a "train the trainers" model, among others. Some other practices, such as creation of school Web sites and use of multimedia presentations, are useful tools that are facilitated by the more fundamental practices.

Policy implications of computer technology in the schools are wide-ranging. They include, among others, the importance of encouraging planning for computer technology, the role of funding for the long term, the importance of accounting for staffing needs (including technical support), and the need to fully address staff development.

The paper outlines each of these topics -- uses, best practices, and policy implications -- and supplements the discussion with some related statistics, a list of selected educational Web sites, a brief description of the important concept of "information literacy," and a list of sources and further reading.

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PREFACE

This paper is designed to give the reader an overview of an issue of current importance: *computer technology in public schools*. While this topic is important nationally and internationally, it is also the focus of local and statewide activity throughout California. The entire subject is likely to be challenging and controversial for a long time to come.

This paper responds to three questions in a relatively informal outline format:

- How is computer technology being used for curriculum-related purposes in California's K-12 schools?
- What "best practices" are emerging?
- How can the state encourage and support the effective use of computer technology in the schools?

This paper is intended to stimulate thinking *about the role of computer technology* as a tool in teaching California's children and as a resource for California's teachers and *about how best to make that role effective*. I am hopeful that this paper will be used as a discussion paper, providing context for examination of specific issues in more detail. It also serves as a stand-alone overview of the subject for those who simply want a short introduction.

Every point in the paper -- uses of computer technology, best practices, and policy implications -- could easily be the subject of another entire paper. Several of the points touched upon here are likely to be expanded into their own full-scale treatments, as this paper is essentially an interim report on research in progress. For those who wish to learn more right away, the list of "Sources and Selected Further Reading" includes studies and reports that delve much more deeply into issues arising from the new role of technology in the schools. An appendix listing selected Web sites provides starting points for exploring how the Internet is being used right now as an educational tool and resource.

My approach to this research was simple and direct: I phoned educators, asked them to reply to the three questions posed above, and asked them to refer me to other knowledgeable people with whom to speak. I also visited some schools to observe their computer technology. My thanks to the people who were kind enough to share time from their very busy schedules to talk with me. I hope to talk with many others I was unable to contact in the time available for preparation of the present paper, and look forward to visiting additional schools this year.

Interviewees included classroom teachers, librarians, principals, county office of education staff members, and California Department of Education personnel. The

interviewees do not constitute a random sample, but were drawn from a variety of settings from one end of California to the other. I also read thousands of messages posted to education-related discussion groups on the Internet, read newspaper and magazine articles, and reviewed books, studies, and reports addressing computers and the Internet in K-12 education. From all of these sources, a multifaceted but consistent picture emerged outlining important points deserving more detailed discussion and analysis.

This paper follows up and expands on a few pages in *The Internet: A California Policy Perspective* (Sacramento: California Research Bureau, 1997) in which I touched on the Internet and K-12 education. Here I am looking at computer technology in the schools a little more broadly. The topic encompasses not just Internet access and resources -- although those are increasingly important and valuable -- but also stand-alone or locally networked computer uses in classrooms, libraries, and labs.

Note that various products and publishers are cited in this paper. Those citations are for the purpose of specificity, but are not intended as product endorsements.

USES OF COMPUTERS IN K-12

If you can conceive of a use of computer technology, it probably can be found *somewhere* in California's schools. With about one thousand school districts and nearly eight thousand schools, California encompasses schools that have only minimal computer technology and schools that have advanced networks and have achieved sophisticated integration of technology into the curriculum. California also encompasses schools that have networks and computers, but are neglecting to make use of them. Likewise, California's more than two hundred thousand teachers encompass the entire range of technical skills, knowledge, and experience and an enormous variety of approaches to technology in the classroom.

The list below reflects the *range* of uses of computer technology, but makes no pretense of suggesting the number of schools or districts employing any of these uses. The focus is on valid, significant types of use, although ones that are not *necessarily* found frequently. It is not my purpose here to emphasize shortcomings or to dwell on outdated or rudimentary uses, but rather to outline more promising current uses. However, published statistics suggest that the norm in the use of computer technology among schools in California is *well* below the sophisticated networks and curriculum integration found in a few districts.[1] Comparative rankings among the states suggest that California is below average nationally in the availability and application of computers in schools. (See Appendix I for selected data.)

Computers may be placed in classrooms (one, a few, or many to a classroom), in a computer lab, in a library/media center, or some combination of those settings. Some of the uses below require a specific setting (for example, one computer in the classroom, with projection equipment and a screen), while others might fit into any of the settings, with appropriate planning and scheduling.

This list reflects current types of uses found in at least some schools, but not necessarily "best practices" and not necessarily in any sort of priority order. The next section lists some best practices offered by people with whom I discussed computer technology in the schools and that I have observed in practice. Some ideas appear in both sections. The list omits purely administrative types of use.

- **Presentation of lessons to a class.** A computer, appropriate software (Microsoft PowerPoint, Roger Wagner Publications' Hyperstudio, or a Web browser, for example), and a projection device enable teachers to present a lesson to the class, incorporating graphics, Web pages, and other information. In essence, this is an updated and enlivened chalkboard or overhead transparency projector. With a connection to the Internet, the teacher can pull information from such sites as the Library of Congress and the Exploratorium for display to the class as part of a lesson. This method is well suited to a one-computer-per-classroom situation. Students may make presentations to the class in the same way. Solid content can be combined with attractive and interesting presentation style.

- **Simulations.** "Oregon Trail" and comparable programs simulate a historical adventure. Programs like Tom Snyder Productions' "Rain Forest Researchers" offer students the opportunity to take part in a simulated research project that integrates multimedia on the computer with workbooks, collaborative activities, and other information resources.[2] Programs of this type may be run on a single computer for use by a small group of students at one time.

- **Teacher research.** Teachers, often with the assistance of school librarians or media specialists, use computer resources to find information on class topics, to locate supplemental materials, to verify or update information, and to help in locating print resources needed for a class. Internet search engines, reference sites, government agencies, CD-ROM disks, and online professional discussion groups (listservs and news groups) can all be used for this purpose.

- **Student research.** Students do research for papers, presentations, and general assignments with the aid of computer-based resources. These resources include encyclopedias, thesauruses, dictionaries, atlases, and other reference works, document archives, and statistical compilations on CD. Resources also include information on the Internet and available through the Web, ftp, gopher, or other means. As online and CD-based research becomes typical in the workplace, classrooms and school libraries are coming to use (or at least to have access to) the same techniques to supplement printed books and magazines.

- **Student reports and presentations.** Students use word processing programs, graphics programs, or other products to format reports and to make classroom presentations of their work. One popular product for this purpose is Hyperstudio, a

product that allows the user to create "hyperstacks" containing text, audio, graphics, and even video (if the needed hardware is available) and to integrate all of these features into a single presentation.

- **Managing science experiments and data.** In some science classes, scientific instruments are connected to computers to assist students in gathering, recording, and analyzing data more reliably than through hand methods and in a way more reflective of how scientific research is actually conducted now.

- **Communications with classes in other schools, states, or countries.** Classes correspond with classes in another area or even on a different continent, to trade notes on local customs, history, environment, and so on. E-mail allows quick responses that would be impossible by conventional postal mail.

- **Communications with scientists and researchers.** Students (or the class as a whole) sometimes send inquiries to scientists working in such areas as space exploration or meteorology. Students in some classrooms collect weather observations and send them over the Internet to be included in a database that combines such student observations with data gathered by scientists. Through the Internet, students may observe travel and research expeditions in distant parts of the world and even post questions for the researchers.

- **Teaching the use of standard types of software.** Typical software applications such as word processors, spreadsheet programs, Web browsers, and graphics programs may be taught as stand-alone topics, similar to the teaching of library research, mechanical drawing, and typing in past years. Computer lab settings are often used for this sort of instruction in preference to classroom settings, although classroom work is possible, too, where enough computers and software are available.

- **Teaching CAD/CAM.** Especially for vocational education courses, teaching with computers is a normal method now, as students will be using computers in the workplace for drafting, landscape design, architectural work, and other activities previously done on paper.

- **Business classes.** Classes in business use computers to teach (and teach by means of) the methods used in the workplace. Everything from basic clerical work to accounting and project management now requires computers in the workplace, and current business classes are reflecting workplace norms.

- **Class or school home pages on the Web.** Many schools now have a Web presence. For example, Truckee High School (http://placercoe.k12.ca.us/ttusd/truckhs/) has posted information about the school, links to the administration and to the county office of Education (Placer County), and extensive educational resource links, categorized by subject.

Figure 1. Birch Lane Elementary School

Netscape - [BIRCH LANE HOME PAGE]
File Edit View Go Bookmarks Options Directory Window Help
Home of the Eagles
Welcome to Our Birch Lane School Community
Birch Lane Elementary School is located in Davis, California.

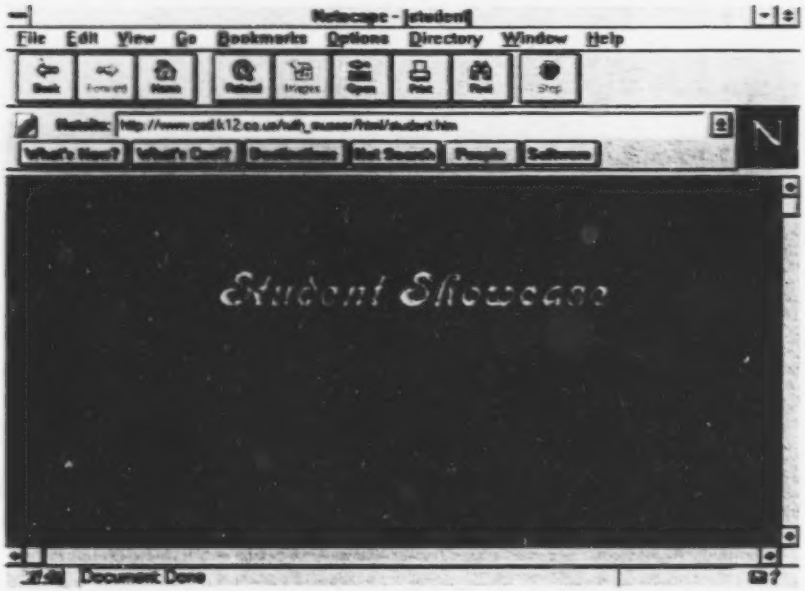
Birch Lane Elementary School, Davis (http://www.birchlane.davis.ca.us/) has posted extensive school information, links to nearby schools, and resource links tied to the curriculum (Figure 1). Links to many California schools with Web sites may be found via (http://www.slocs.k12.ca.us/calpage.htm), "California County Offices with Web Servers."

- **Posting student work on the Web.** Some schools post examples of student work online. For example, Ruth Musser Middle School, Rancho Cucamonga (http://www.csd.k12.ca.us/ruth_musser/html/student.htm) has posted the student newspaper, students' reports on whales, computer projects, and science reports (Figure 2).

  The computer plays more than one role in such applications. First, it is a tool in research. Second, it is a tool in creating the presentation (through graphics, word processing, and possibly other software). Finally, it is a means for posting the work on the Web.

  Some teachers have found that students are motivated to do better work, and to take more pride in their work, when papers and projects are posted on the Web for all the world to see. Such posting also gives parents a chance to see what the students are doing.

Figure 2. Ruth Musser Middle School



- **Drill and practice.** Finally, a long-established use of computers in the classroom is to drill students in mathematics, reading, and other subjects. For example, the computer offers an addition problem and the student enters an answer; the process repeats through some number of problems. The program might offer immediate feedback, or might simply calculate a score at the end. This is a type of use that dates back to the first introduction of microcomputers into classrooms and labs and can be carried out on even the oldest microcomputers. Newer software uses multimedia effects to make the presentation more engaging.

BEST PRACTICES

What constitutes "best practices" varies widely and depends on factors such as school size and location.

What is a best practice in one school or for one class might be less than best for another school or for a class or student with different needs. However, certain fundamental best practices apply everywhere. The following list includes fundamental practices as well as some more specific ones. The list includes some of the ideas found in the "Uses" section above. Please bear in mind that all of these ideas are presented here for discussion on the basis of preliminary research, in hopes that practitioners will add other ideas and point out needed improvements or corrections. Each of the practices listed below could easily be the focus of an entire paper in itself.

- **Plan first, implement later.** The most successful schools and districts have taken the time to plan so that purposes and standards are clear, hardware and software are

compatible and supportable, the technology will contribute to the curriculum, and continuing costs of maintenance, upgrading, replacement, and support are accounted for. Planning of course also considers such system issues as adequate security for computers and peripherals (theft and vandalism deterrence) and placement of sensitive equipment in weatherproof rooms with appropriate temperature control. Planning encompasses the purely technical issues of selection, installation, and maintenance *and* the "people" issues of training and coordination. One statewide leader in the use of technology, the New Haven Unified School District, took a full year to plan its infrastructure with the aid of consultants before installing a network. The planning, in turn, started with a detailed needs assessment.

- **Provide staff development.** *This is the single concept cited by every person I interviewed, and mentioned or alluded to in every published report on computers in schools.* It is not only a best practice to provide staff development, it is an *essential* one if computer technology is to be used and used effectively in classrooms. However, there are different kinds of staff development, of which training in the mechanics of using the hardware and software is only one. There are also different levels of formality, from highly structured workshops and inservice sessions to the informal encouragement of the sharing of ideas and knowledge among staff. An effective staff development plan will encompass a range of techniques.

- **Train teachers specifically in the use of technology in delivering curriculum.** Although it overlaps the previous point, this practice is so important as to require special attention. Only through such training will teachers be comfortable and competent in using technology as a tool, just as they use chalkboards, books, maps, art supplies, videos, field trips, and a host of other techniques and resources. The importance of this practice -- training in curriculum integration -- was underlined by nearly everyone I interviewed and is an important point in numerous articles and reports.

- **Provide a properly equipped, appropriately stocked, and well-staffed library media center.** The explosive and disorderly growth in information available on the Internet requires trained librarians who can assist teachers and students in finding and evaluating information and in deciding when print resources are more suitable. A school library with a good selection of appropriate books, periodicals, and other print resources (as well as CD-ROM publications) alongside Internet access terminals and staffed by certificated personnel (library media teachers) is an important asset. It is also a vital asset for the library media center's Internet terminals to provide access to Web pages developed specifically to organize links to high-quality, professionally evaluated Internet resources that support the school's curriculum. Staffing of school libraries has been a particularly weak area in California. A national report published in 1994, based on a survey, noted that, for purposes of selecting survey participants: "unacceptable, *except in California*, were people with the title 'volunteer,' 'aide,' or

'clerk.' (*These titles were accepted in California because often such people are the only staff present in the library media center (LMC).*)"[3] (Emphasis added.)

- **Provide technical staff to support the technology.** Teachers need to be free to teach, and they are badly used if they must be technicians, too. It is a best practice to provide capable and sufficient technical support to take care of hardware and software installation and maintenance and to do troubleshooting beyond the elementary level that might reasonably be expected of an end user.

- **Use technology to present curriculum rather than to "teach technology."** Schools must make technology a normal, functional part of the teaching process. That is, rather than devoting class time to "learning computers," the teacher plans lessons for which computer resources are a means, not an end. (Of course it is a different matter when the subject really IS the technology, as when a high school offers a class in Visual BASIC programming or a vocational education class in computer repair and maintenance.)

- **Provide leadership and example.** In the use of technology as in other areas, leadership counts. That is, if a school is to make effective use of technology, the principal and other administrators must take the initiative to use technology appropriately, share a vision of effective technology use with the teachers, and plan for training and support along with hardware and software acquisition. The same concept applies at the district level, where the example and leadership provided by the superintendent affect principals across the district.

- **Use the school's network as a tool for administration-faculty communications.** Where a school does have a network and teachers have networked computers, good results have been obtained when the principal has mandated electronic communications in place of paper-based methods. That is, daily announcements are sent to teachers via e-mail. Teachers are required to communicate with the administration via e-mail. This encourages teachers to become accustomed to computer communications in the course of normal daily work.

- **Conduct professional communications via the Internet.** Although it was rarely cited explicitly by those I interviewed, observation over several months suggests that online discussion groups are valuable tools for educators. Time and again, questions posted on LM_NET or EDTECH drew responses from other list members with specialized knowledge that might otherwise have been difficult to find. Topics have covered every conceivable subject, from technical details of network management within a school to the birth date of "Clifford the Big Red Dog."

  Very often the questions posted online have had to do with books -- getting exact titles and authors, finding out where to buy specific books, or sharing notes on challenges made by parents. This is not surprising, given that the membership of

LM_NET is predominantly school librarians/library media specialists (called library media teachers in California). Some of the questions have been very simple and easily answered, and others have been very complex, resulting in lengthy threads of commentary on management issues. Many have drawn responses from across the country and even from several continents.

- **Support and use SCORE.** This acronym stands for Schools of California Online Resources for Education. SCORE (administered by CTAP, the California Technology Assistance Project) represents collaboration among teachers, districts, county offices of education, and other individuals and organizations across California. SCORE designates a series of lesson plans and resources posted on the Web. The lessons are designed by teachers to complement California's curriculum guidelines. The SCORE subject areas include History-Social Science, Mathematics, Language Arts, and Science. Some interviewees explicitly named SCORE as a best practice because it provides tested, teacher-developed guidance in using online resources within the California curriculum. (Some of the people I interviewed had contributed to SCORE.) See the appendix for Web addresses (URLs) of the SCORE sites, and a summary of the criteria for inclusion of a project.

- **Earmark at least 30 percent of the money allocated to technology to fund staff development.** That funding covers training in the mechanics of using computers, running software, understanding computer communications (e-mail, Internet access), and handling simple troubleshooting appropriate for an end user. More important, it pays for training in how to put the technology to effective use in the classroom. Without staff development, the technology may be poorly used or not used at all.

- **Train the trainers.** It can be efficient and effective to begin by carefully training a selected core group of teachers. Each of those teachers then becomes the trainer of another group. The process repeats. In this manner, beginning with a relatively small number, training can be brought to an increasing audience, and in the process those who have become trainers increase their own expertise and fluency with the technology. They may also model techniques of using the technology as a teaching tool.

- **Help teachers to get their own computers.** Teachers who have their own computers have more time to learn and become comfortable with the technology. Classroom teachers seldom have enough time on the job to learn, practice, and experiment. Programs to lend district-owned computers for teachers' home use, assist in selecting a suitable computer, or even to help finance the purchase of a suitable computer and software can facilitate learning and speed up the process of integrating the technology into the classroom. (For more information related to this point, see my discussion paper "Computer Fluency: Teachers and the New Technology," posted at http://www.library.ca.gov/CRB/working/experts.html.)

- **Select methods to meet the needs of the students.** This may seem excessively obvious. I mention it because one interviewee pointed out that the often-denigrated drill and practice programs (demonized as "drill and kill") are an effective tool for *some* students, and *for those students* they constitute a best practice. The fundamental issue is not whether drill and practice programs (or any other specific technology-based educational techniques) are a best practice across the board. Rather, it is to discern what methods work best for which students. ***Properly matching tools and techniques to students is the best practice.***

- **Create school Web sites.** As the examples in the "Uses" section show, a school Web site can both inform the community about the school and serve as a resource of immediate value in the curriculum, a resource that can serve teachers, students, and parents. As there is increasing access to the Internet, both through home computers and through public access in libraries and other settings, school Web sites are an increasingly promising tool by which schools may communicate with students, parents, and the community at large. School Web sites created and managed by library media teachers can be an effective means of giving quick and simple access to selected Internet resources of high quality that specifically and effectively support the school's curriculum. Such pages may also be a useful staff development resource.

- **Create multimedia presentations.** Both teachers and students have made use of multimedia presentations to animate topics and issues. Such presentations include graphics, video, sound, and text and may be tailored to specific topics. The commercial product called Hyperstudio, which is designed to simplify creating multimedia presentations, was mentioned specifically by many of my interviewees as an effective tool for students and teachers. While this should not be taken as a product endorsement, it is certainly an endorsement of the concepts embodied in the product and its usefulness as a tool in the classroom. Creation of such presentations both adds interest to class and student projects *and* teaches students tools and concepts that are of increasing value in business and professions.

Priorities among the best practices

The above list is not necessarily in priority order. Setting priorities is especially difficult in the light of the ways in which the practices interrelate and the ways in which some practices facilitate others. If one had to pick out some of the practices as most significant (which may really mean "most fundamental"), they would include:

1. Plan first, implement later
2. Provide staff development
3. Train teachers specifically in the use of technology in delivering curriculum
4. Provide technical staff to support the technology
5. Provide a properly equipped, appropriately stocked, and well staffed library media center

A school that has carried out all five of those practices is in an excellent position to follow through with all of the other best practices and to support effective use of technology over the long run. An effective planning process will address needs for staff development, curriculum integration, technical support, and the role and management of the library media center, all in the context of the school's overall educational goals.

POLICY IMPLICATIONS: SUPPORTING AND ENCOURAGING EFFECTIVE TECHNOLOGY USE

The topic of computer technology in K-12 education is sprawling and encompasses many difficult issues. The sections below touch on some ideas for state- and local-level support of effective technology use in the schools, but only suggest topics that require much fuller exploration. Most, if not all, of these points are well recognized in the literature on educational technology and by those involved in the field.

There is some overlap among the categories, so topics may be addressed from more than one point of view. Some of the points touched on in this section draw from ideas and information gathered in the course of this research, but not necessarily reported in the preceding sections. Some of the points pertain specifically to the state's systemwide role in supporting and encouraging technology, and others focus more on the specific role of school and school district leadership.

Planning

- The state can help to assure that technology plans offered by districts applying for grant funds have been specifically designed *by and for* the district, not assembled from pre-existing templates or other districts' plans. To this end, it is important that timelines for grant programs, such as the Digital High School grants, allow for the time necessary for effective planning. That time would allow involvement of students, teachers, parents, school administrators, district administration, and technical experts in designing a coherent and purposeful plan.

- Technology planning must entail consultation within the district and include representatives of all affected sectors of the district: school board, superintendent's office, school-level administration, teachers, parents, and students. A draft of the plan should be made available for public comment before final adoption. Such consultation may be encouraged by grant conditions that so specify.

- Appropriate and specific technical consultation is necessary for effective planning. Grant conditions that specify technical consultation as part of the process will help to encourage effective planning.

- In addition to technology specifications, plans must encompass: integration of technology into curriculum delivery; staff development; ongoing support, maintenance, and replacement; and teaching of important information literacy (information problem solving) skills in coordination with the school library media program. (See the brief explanation of "information literacy" in Appendix III.)

Funding

- Long-term funding for technology must be addressed in the technology plan and in the district's budget. The long-term view must encompass ongoing needs for maintenance and repair, scheduled replacement, training, and support. This helps to assure that technology, once installed, will not become obsolete or otherwise unusable.

- Funding must be sufficient for all needed copies of software or site licenses. Districts must not, even inadvertently or unknowingly, rely on illegal software, a problem that some believe to be common and potentially very risky. Not only is the use of "pirated" software illegal, it sets a bad example and it deprives the teachers and other staff of support to which properly registered, legitimate software would entitle them. This is an issue that spans planning, funding, *and* training.

Staffing

- Schools and districts need *technicians* to handle the technical work. Teachers cannot be expected to fill that role. Those who try to be teachers *and* technicians *and* consultants may do all of those jobs less than optimally and may simply burn out from the strain. To this end, staffing standards for schools should account for the technical and support demands placed by educational technology, especially computers, networks, and the Internet.

- Pay scales must take account of the market value of technical expertise so that teachers and librarians with much-needed technical skills are not lost to higher-paying private-sector jobs. Anecdotal evidence suggests that this is a matter for concern, and the demand for technically trained staff in many industries suggests that schools will continue to face competition for people with strong technical skills.

- Schools must have appropriate libraries and library staffing. Specifically, certificated Library Media Teachers who have recent training in technology use should staff school libraries, rather than only volunteers or less qualified assistants.

Training (staff development)

- Districts must assure that teachers receive training in the concepts and practical aspects of the technology and, equally important, in the effective and appropriate use

of technology within the curriculum. To this end, all parties (state, district, and school) must plan for sufficient funding to meet the need both for initial training and for ongoing training as new developments and new personnel require.

- All levels should recognize, support, participate in, and publicize the California Technology Assistance Project (CTAP) programs and resources. A notable example of the resources and information available through CTAP is the Region 2 multi-level training and certification program. That program includes both the basic use of hardware and software ("Level 1") and the vital information literacy and curriculum integration skills ("Level 2") for the teacher. For an outline of this program, see http://www.ctap2.bcoe.butte.k12.ca.us/3tiersdp.html.

- Where feasible, districts -- and the state if necessary -- should take steps to assist teachers in acquiring their own computers. Such steps could include arranging group buys at a discount, funding purchases in whole or in part (with appropriate conditions as circumstances dictate), facilitating financing through payroll deduction, and, at the state level, tax credits for school personnel, including, but not necessarily limited to, teachers, who purchase computer hardware and software for professional purposes.

Communicating

- A statewide educational network managed by the state and directly providing communications services might be an effective means of disseminating information on California computer technology resources and best practices and of guaranteeing equitable access for schools and school personnel in economically or otherwise disadvantaged areas. This is an enormously complex issue, and one that may be appropriate to examine in detail.

- Leaders at all levels of California education should assure that school officials and teachers know about the technology-related resources provided by or in association with the State Department of Education. These resources include CTAP, SCORE, the department's own Web site, and publications.

Curriculum Integration

- Curriculum guidelines should address the role of technology as a tool in presenting curriculum, not just as an object of instruction. That is, guidelines must address teaching *with* technology in ways appropriate to all curriculum areas.

- Training of teachers must emphasize the appropriate uses of technology in delivering curriculum and in meeting information literacy (information problem solving) goals. It is likewise important that no software or other technology tool be introduced into the classroom unless teachers are trained in its use. The obverse of this is that, so that

training does not go to waste, needed resources are made available for teachers to put what they have learned to use in the classroom.

Evaluating

- There must be a mechanism for evaluating the uses of technology and standards by which to determine whether objectives are being achieved. Grant programs should include an evaluation component addressing all major aspects of the project.

CONCLUSION

In short, to use computer technology effectively, schools must:

- plan carefully in cooperation with all affected elements of the school community,
- train well and on a continuing basis,
- provide technical support,
- budget consistently for the long term and in amounts sufficient to cover actual need,
- integrate technology into the delivery of curriculum, and
- continuously evaluate methods and outcomes.

Used well, computer technology is a valuable tool for schools. In addition, appropriate use of the technology assists in preparing students for further education, work, and participation in a society that is increasingly dependent on computers and on digital communications and information resources. But effective use of technology is not a simple matter, nor is it something that any school, let alone the system as a whole, can address on a one-time basis and consider to be a completed matter.

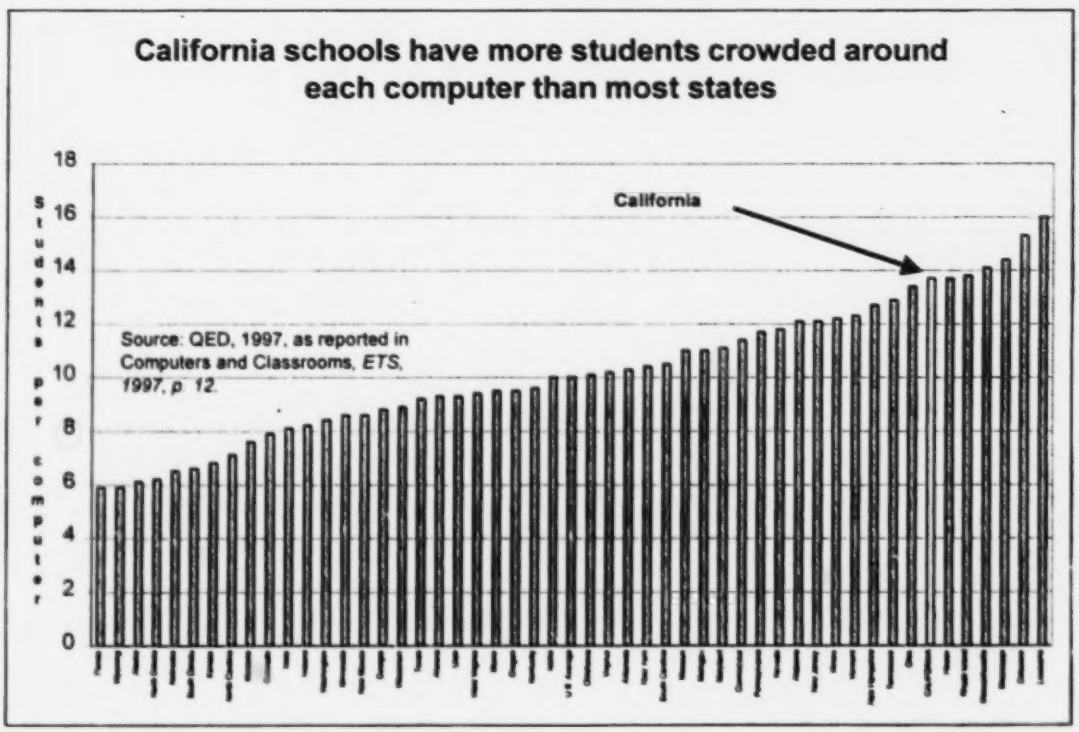
APPENDIX I: SELECTED STATISTICS ON COMPUTER TECHNOLOGY IN CALIFORNIA K-12 SCHOOLS

Following are a few, selected statistics on computer technology in California's schools. Some of the statistics represent comparisons among the states, and others pertain specifically to California.

Students per computer

One broad measure of accessibility of computers is the simple ratio of students per computer. While this is a very imperfect measure, it does at least allow quick, general comparisons. By this measure, California, at 13.7 students per computer, is behind most states and behind the U.S. average of 10 students per computer (Figure 3). Six states have a higher (that is, worse) ratio than California.

Figure 3: Students per computer, by state



A comparable pattern is seen with respect to students per multimedia computer. (A multimedia computer is one that can display video and play sound. This is the standard now typical of home computers selling for around $1,000 and is a necessary level of technology for current educational software, multimedia reference works, and presentation programs such as Hyperstudio, as well as much Worldwide Web content.)

Quality Education Data's 1997 figures show California, at 36.9 students per multimedia computer, behind the U.S. average of 23.7, and behind most states.[4] California is ahead of nine states by this measure. The leading state on this measure, according to QED's data, is Florida, with a ratio of 8.5 students per multimedia computer. Twenty-two states have a lower student to multimedia computer ratio than the U.S. average. Eighteen additional states have a lower ratio than does California but have a ratio higher than the U.S. average.

Research conducted for the California State Department of Education in the fall of 1995 found wide variations among California schools with respect to student-computer ratio.[5] About ten percent of schools had a ratio of less than five students per computer, while about ten percent had a ratio exceeding 25 students per computer. The average was a little under 15 students per computer. (This study, by Rockman et al and RPP International did not report separately on multimedia computers.) A fall 1996 follow-up survey by Rockman/RPP showed some improvement (but not dramatic by any means) in this and other measures of technology in California schools.

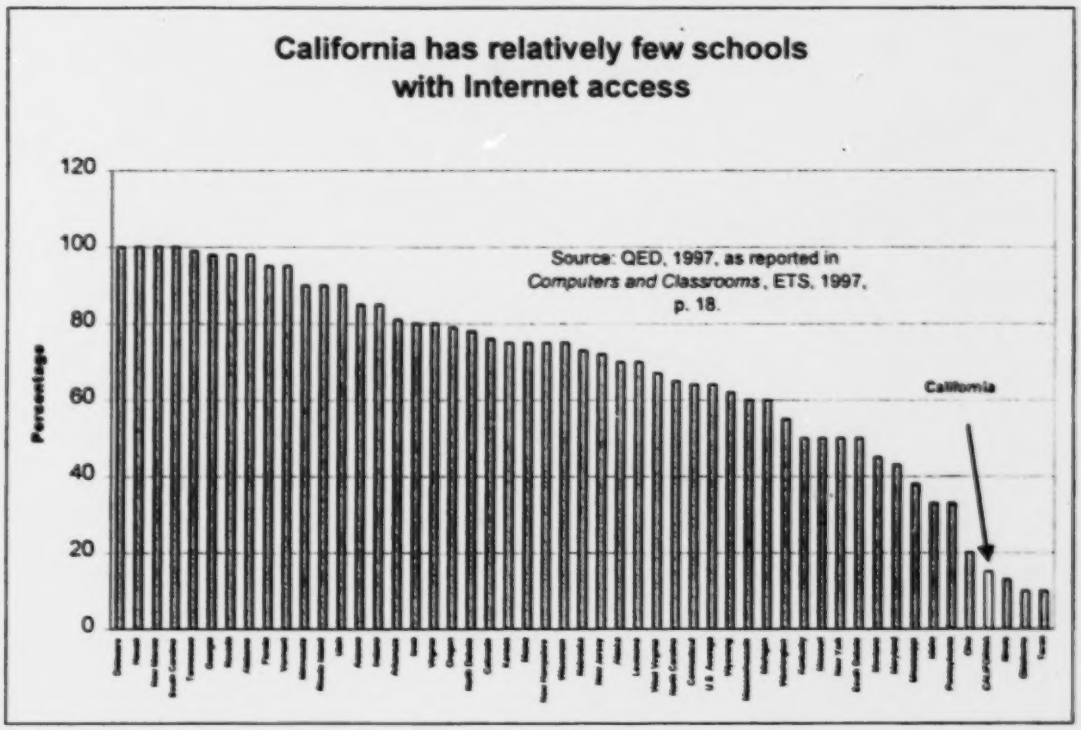
Internet access

Internet access is another broad indicator of computer technology in the schools, and one that is not necessarily precise. Access may be via terminals in a library media center, in a computer lab, in selected classrooms, or in most or all classrooms. Access may be nominal, if few teachers make use of the resources available on the Internet or if access is severely limited by a slow connection or other factor. Nonetheless, in terms of this broad comparison, California ranks, according to Quality Education Data, near the bottom among U.S. states, and, at 15 percent, far below the U.S. average of 64 percent of schools with Internet access (Figure 4).

One factor limiting Internet access in California schools may be the lack of telephone lines in many classrooms. The Rockman/RPP report found that, as of fall of 1995, more than a third of schools (37 percent) had telephone lines in *no* classrooms, and 44 percent had telephone lines in 25 percent or less of classrooms.[6]

The most significant limitation on Internet access may exist despite nominal access itself. That factor, which is not captured by statistics such as those summarized here, is teachers' and librarians' knowledge of the Internet and how its resources may be used as a curriculum resource. The Rockman/RPP report estimated teacher participation in technology-related staff development to be limited, as of fall of 1995. Only 21 percent of schools had more than 75 percent of teachers participate in training in technology integration, and in 54 percent of schools a quarter or less had participated in technology integration training. Participation in basic technology skills training and applications training (use of software) was more frequent.

Figure 4. Internet access, by state

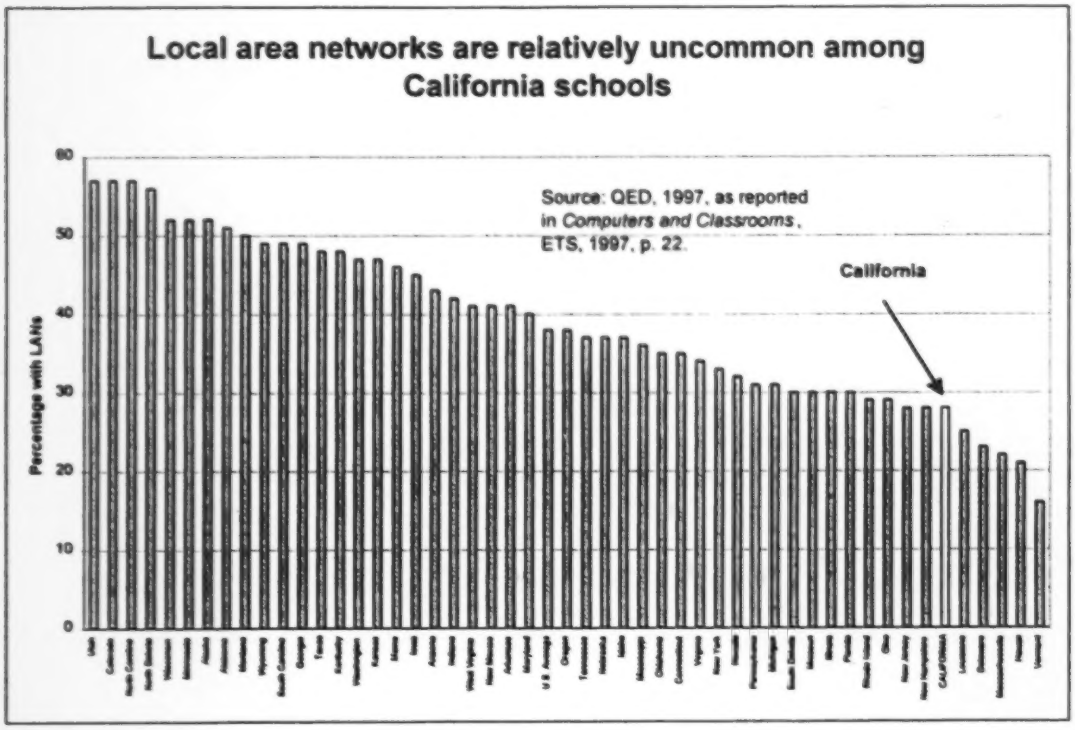


The Rockman/RPP report found Internet access to be available in few classrooms as of spring 1996 (data based only on schools that had received grants under SB 1510). Typically, no classrooms or relatively few (under 25 percent) had Internet access in those schools. Access was "schoolwide" (in more than three-quarters of classrooms) in only about 21 percent of the SB 1510 schools.[7]

Local area networks (LANs)

Like other measures of technology in schools, the presence of local area networks is imperfect. LANs can be useful tools, though, and their presence is one measure (other things being equal) of a school's adoption of technology. At 28 percent, California is below most states and below the U.S. average (38 percent) in the percentage of schools with local area networks, according to Quality Education Data (QED) 1997 figures. Seven states have a percentage equal to or below that of California (Figure 5).

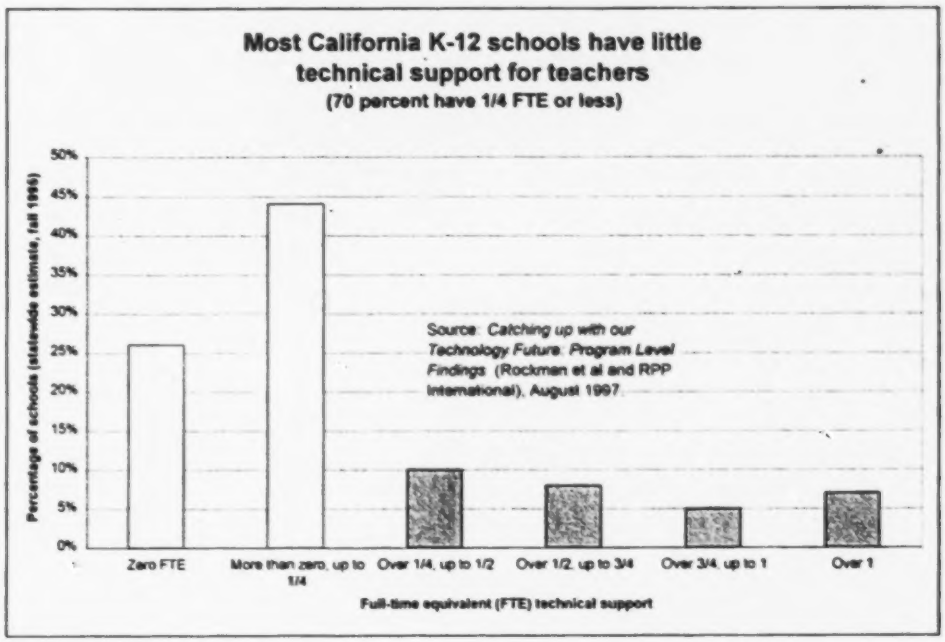
Figure 5. Local area networks, by state



Technical support

One of the most vexing issues relating to computer technology in schools is, not surprisingly, technical support for computer hardware, software, peripherals, and networks. The Rockman/RPP study found that schools, as of fall of 1995, typically had one-quarter or less full-time equivalent (FTE) of technical support (Figure 6). Although this is a rough measure, it does suggest an area requiring both further investigation and careful attention as expectations for technology in the schools increase and become more sophisticated.

Figure 6. Technical support



APPENDIX II: SELECTED EDUCATIONAL WEB SITES

Following are some Worldwide Web sites illustrating the educational use of the Internet in K-12 and resources available to teachers, students, and parents. This is only a tiny sampling. There are many widely varied and sometimes truly extraordinary Web sites for teachers and for students. A broad selection is posted online at http://www.library.ca.gov/CRB/98/03/k12appen.html. This page includes links to sites that in turn provide hundreds more links to education-related resources. One of the best-known and widely used educational resource sites is Kathy Schrock's Guide for Educators (http://www.capecod.net/schrockguide/). Another site of notable value is Peter Milbury's School Librarian Web Pages (http://www.cusd.chico.k12.ca.us/~pmilbury/lib.html). (Peter Milbury is School Librarian and Mentor Teacher at Chico Senior High School, in Chico, California.)

Needless to emphasize, there are many, many fine resources available on CD-ROM and other digital media -- including the database of the California Instructional Technology Clearinghouse -- although increasingly research and reference programs are integrated across CD-ROM and the Internet.

SCORE (Schools of California Online Resources for Education)

The following list of SCORE's lesson criteria is from the SCORE History-Social Science site, http://www.rims.k12.ca.us/SCORE/evalcrit.html:

All lessons and activities created for SCORE will:

- Include a lesson sequence that is clear, complete, and doable
- Include information literacy skills
- Be grade and developmentally appropriate
- Focus on a topic that is clearly connected to California curriculum frameworks
- Include a task that poses problems with multiple solutions and incorporates a variety of learning strategies
- Correlate with related fields of study and encourage multiple modes of production
- Enable students to actively construct knowledge and meaning
- Embed a variety of resources
- Include a clear criteria for evaluation of student project
- Include a clear purpose that is achieved through the activity or lesson

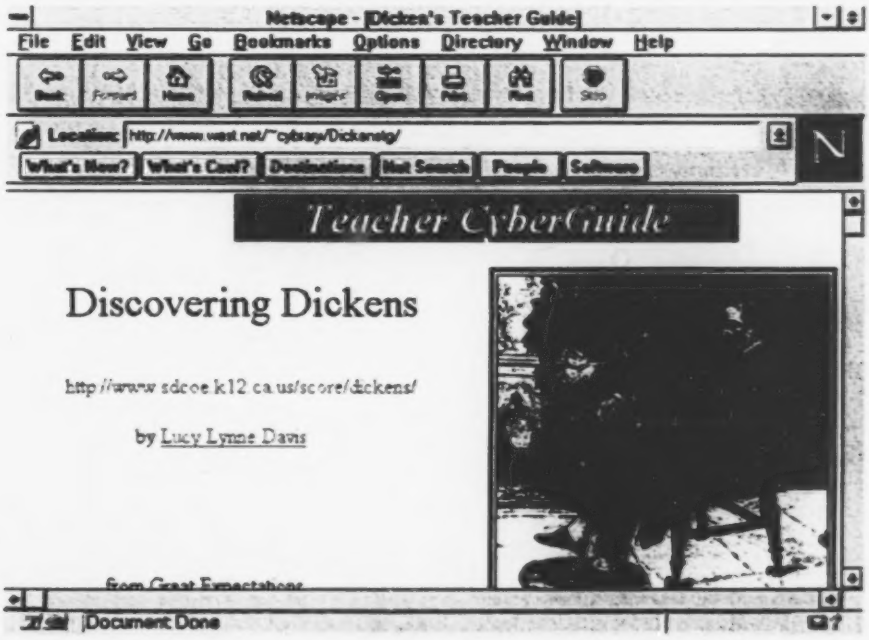
The four subject areas are listed below, with an URL for each.

- **History-Social Science**: http://www.rims.k12.ca.us/SCORE/

- **Mathematics**: http://www.kings.k12.ca.us/math/
- **Language Arts**: http://www.sdcoe.k12.ca.us/score/cla.html
- **Science**: http://scorescience.humboldt.k12.ca.us/

These sites offer extensive resources, both specific lesson plans categorized by grade level and links to additional resources. The lessons, developed by California teachers, include links to Web-based resources that contribute directly to achievement of unit objectives. For example, the "Discovering Dickens Cyberguide" (Figure 7) provides several lesson plans and extensive links to resources for a grade 6-8 exploration.

Figure 7. "Discovering Dickens Cyberguide"



Other sites

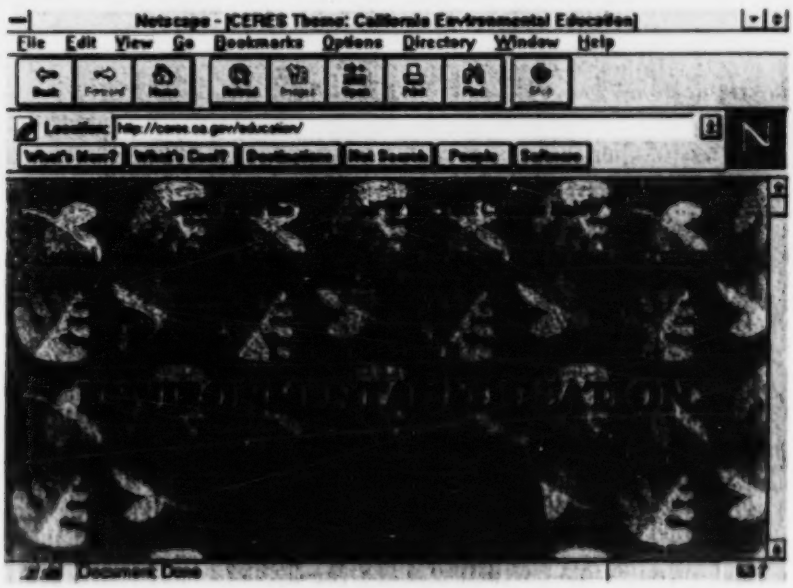
These are only a few sites representing the rich resources now available on the Internet and available to any classroom or library with a connection and a moderately well equipped computer.

- **The Internet Public Library** (http://www.ipl.org) provides links to reference information and to more than 1,100 online newspapers from around the world, in many languages. This is an excellent set of resources for students and for teachers. It is only one of many online libraries and reference centers that provide immediate access to well-organized information on countless topics.

Comparable sites include the University of California Librarians' Index to the Internet (http://sunsite.berkeley.edu/InternetIndex/) and the California State Library (http://www.library.ca.gov). In a similar vein, the Encyclopaedia Britannica Internet Guide (http://www.ebig.com) is a free service that offers search-engine access to sites reviewed and selected by Britannica editors.

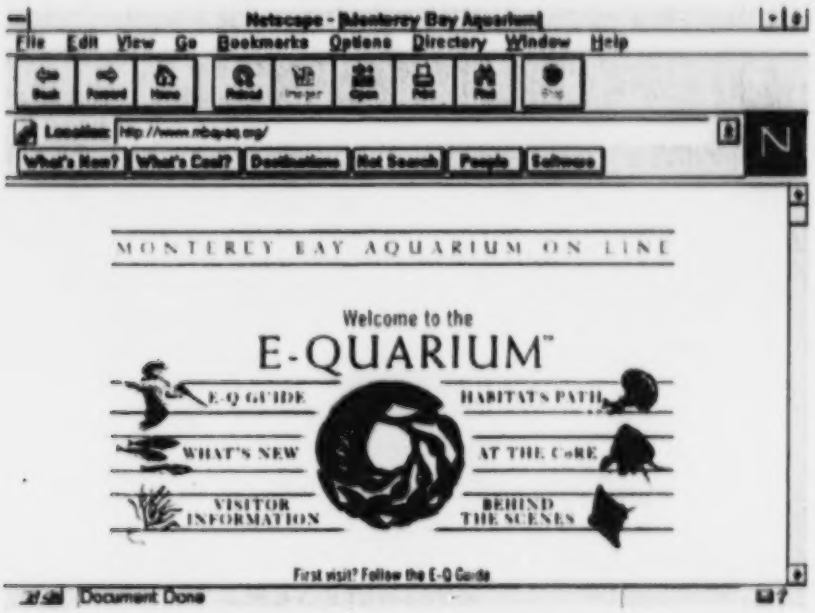
- **The CERES (California Environmental Resources Evaluation System) "Environmental Education" site** (Figure 8) provides links to many curriculum resources (http://ceres.ca.gov/education/).

Figure 8. CERES California Environmental Education



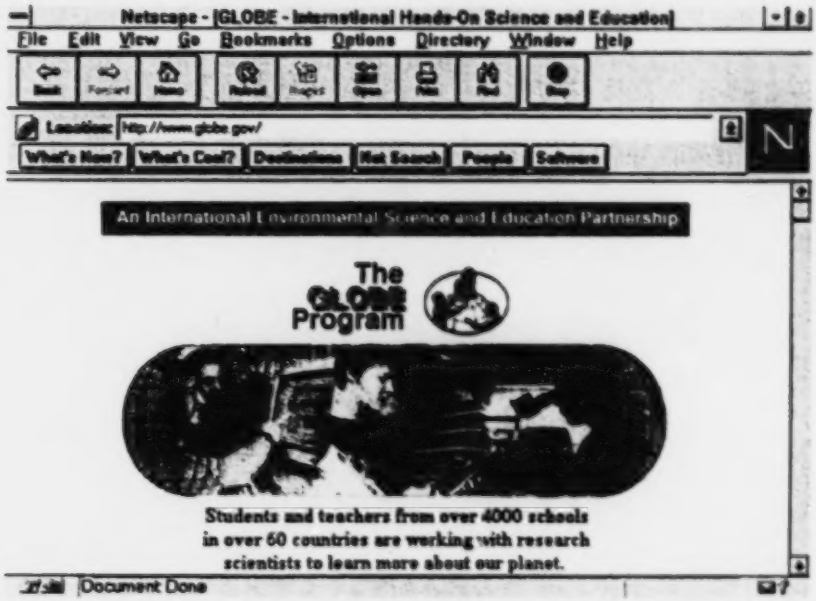
- **The Monterey Bay Aquarium On-Line** (http://www.mbayaq.org/) offers a virtual tour of one of California's great scientific and environmental resources. The Aquarium's site (the "E-Quarium," Figure 9) offers information on the ecology of the Monterey Bay, on the workings of the Aquarium itself, and more.

Figure 9. Monterey Bay Aquarium



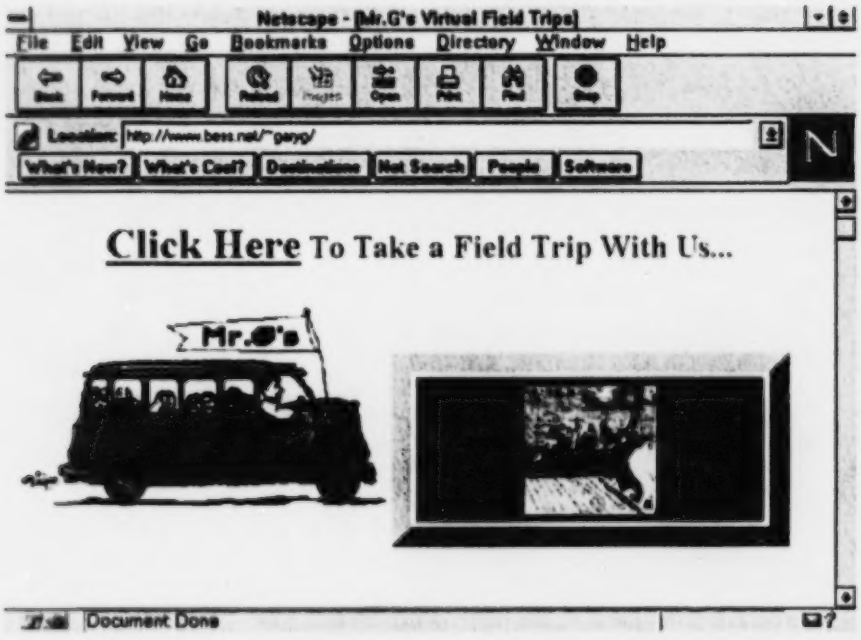
- **The GLOBE program** (http://www.globe.gov/) is a federally sponsored site supporting science instruction (Figure 10). Quoting from the site: "GLOBE students make a core set of environmental observations at or near their schools and report their data via the Internet. Scientists use GLOBE data in their research and provide feedback to the students to enrich their science education. Each day, images created from the GLOBE student data sets are posted on the World Wide Web, allowing students and visitors to the GLOBE web site to visualize the student environmental observations." Birch Lane Elementary School in Davis is one of the participating schools.

Figure 10. The GLOBE Program


Netscape - [GLOBE - International Hands-On Science and Education]
File Edit View Go Bookmarks Options Directory Window Help
What's New? What's Cool? Destinations Net Search People Software
An International Environmental Science and Education Partnership
The GLOBE Program
Students and teachers from over 4000 schools in over 60 countries are working with research scientists to learn more about our planet.
Document Done

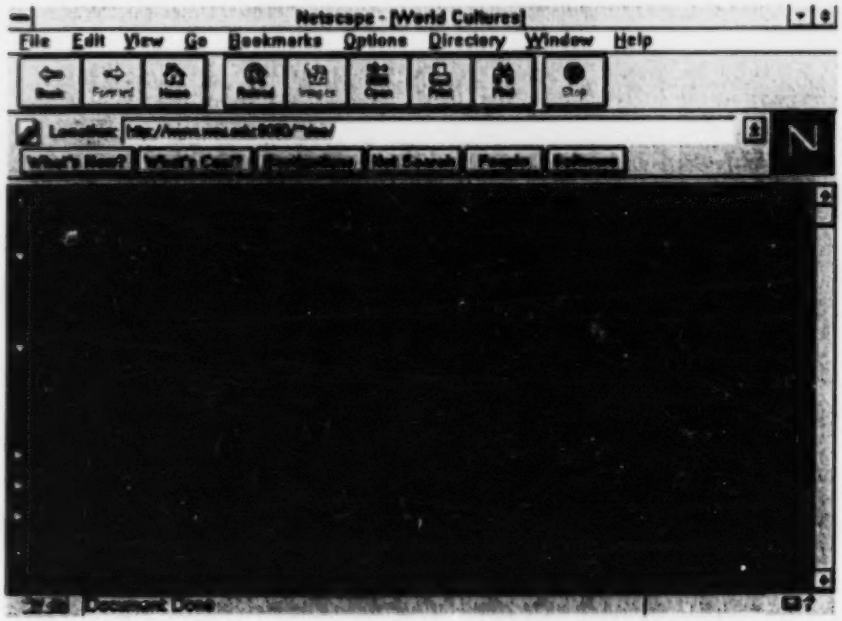
- **Mr. G's Virtual Field Trips**, a creative site offered by Gary Gillespie, a teacher in the State of Washington (Figure 11). This site provides visual tours, with commentary, of the Pacific Science Center, the Port of Seattle, and more (http://www.bess.net/~garyg/trips.htm).

Figure 11. Mr. G's Virtual Field Trips


Netscape - [Mr.G's Virtual Field Trips]
File Edit View Go Bookmarks Options Directory Window Help
Click Here To Take a Field Trip With Us...
Mr.G's
Document Done

- **World Cultures: An Internet Classroom and Anthology** is a vast resource collection for the study of cultures and history (Figure 12).

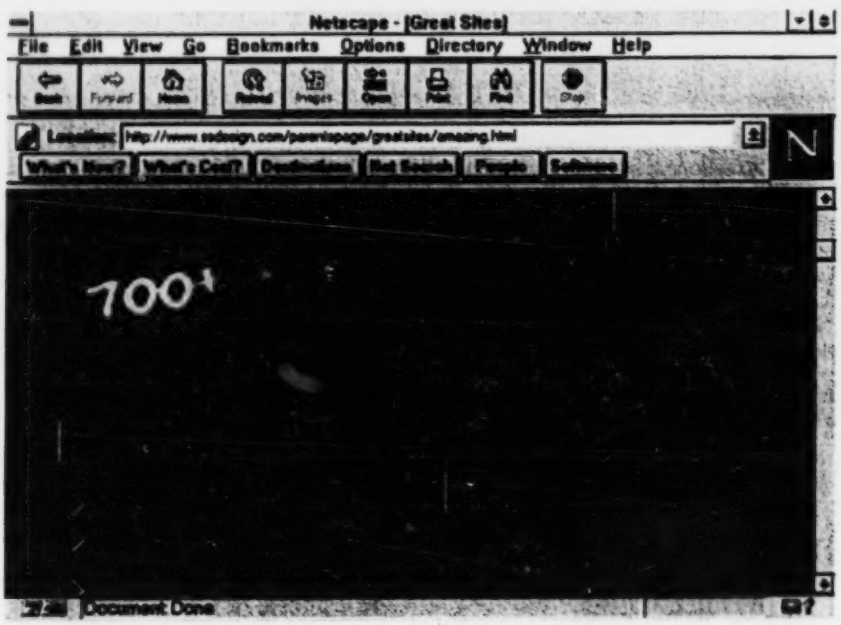
Figure 12. World Cultures



- **Tom Snyder Productions** is a well-regarded commercial educational software publisher (http://www.teachtsp.com/). The company's site provides product information and even some downloadable demonstrations. Those who wish may also request a CD-ROM disk with demonstrations of selected programs, including "Rain Forest Researchers." (I have a copy of the demo disk, and it is fascinating. It requires a multimedia PC or Macintosh.) This is an interesting introduction to imaginative and pedagogically sound educational software. This company also publishes *Great Teaching in the One-Computer Classroom*, by teacher David A. Dockterman, a guide to making effective use of a single computer per classroom.

- **"700+ Great Sites,"** compiled by the Children and Technology Committee of the Association for Library Service to Children, a division of the American Library Association, provides categorized links to educational resources (Figure 13). As a site selected and posted by a library organization, "700+ Great Sites" (http://www.ssdesign.com/parentspage/greatsites/amazing.html) is an unusually accessible and reliable resource for students, teachers, and parents.

Figure 13. "700+ Great Sites"



APPENDIX III: INFORMATION LITERACY

Among the developments accompanying the growth of digital media and their entry into the schools is a focus on "information literacy." Going beyond traditional notions of literacy -- competence in reading and in understanding the written word -- information literacy looks at more complex skills for finding, evaluating, and putting to use information from today's varied sources, both print and digital (online and offline). Especially in view of the vast new access to information (both valid and wildly invalid) on the Internet and in CD-ROM-based collections, this concept is receiving wide attention among educators.

Robert Skidmore, of the Eau Claire Area School District in Wisconsin, posted the following comment to a new e-mail discussion group (a "listserv") called DIG_REF, or Digital Reference. In commenting on some previous messages, Mr. Skidmore stated (in part):

> Things have changed so much since the old days (last year) given the amount of information now available and the access to it. One of the additional efforts we need to make now more then ever is to stress the "critical viewing" of information. Not all information is created equal and people need to understand the channel to evaluate the information. This has become a major effort in our organization: *Information Literacy*.
>
> No longer can we just teach people to locate but have to get them to ask who wrote and why did they write it. Such a large task will only be accomplished by all "information professionals" working together. K-12, postsecondary, public libraries, private libraries and others will all have to go after it.

It is a sign of the times that the Digital Reference mailing list membership grew from zero to over 1,000 within a week or ten days of the announcement of the list. Mr. Skidmore's note capsulizes what may be the most fundamental issue facing information professionals in education now: the need to define, develop, and encourage information literacy.

The "information literacy" concept is outlined in more detail in a handbook by David V. Loertscher, *Reinvent Your School's Library in the Age of Technology: A Guide for Principals and Superintendents* (San Jose, CA: Hi Willow Research and Publishing, 1997 [preview edition]).

APPENDIX IV: SOURCES AND SELECTED FURTHER READING

This discussion outline draws from a wide variety of published articles, reports, papers, and books. Predominantly, though, it draws from interviews with teachers, librarians, and administrators in California's public schools and school districts and from e-mail correspondence from teachers and school librarians across the country.

I have reviewed several thousand e-mail messages from teachers and school librarians, giving a broad view of applications of computer technology in the schools and of issues arising from the technology. Some of the uses and best practices identified in this discussion outline reflect the observed use of the Internet by participants in the LM_NET and EDTECH Internet-based discussion groups. Archives for LM_Net, EDTECH, and many other education-related discussion groups may be searched via links at "AskERIC Education Listserv Archive," http://ericir.syr.edu/Virtual/Listserv_Archives/.

The people I have spoken or corresponded with do *not* constitute a scientific sample or a statistically valid cross-section of teachers and schools. Nonetheless, I believe that the concerns and observations they have provided do reflect the broad range of experiences and issues arising today with respect to computers in California's schools. As varied as their perspectives have been, there was *substantial agreement on core issues*. Some key points were unanimously accepted among those with whom I spoke.

The following selected documents are suggested for further reading, and reflect varying perspectives.

California Department of Education. "Connect, Compute, and Compete: The Report of the California Education Technology Task Force." Posted at http://www.goldmine.cde.ca.gov. Superintendent of Public Instruction Delaine Eastin convened the task force in October 1995, and the report was issued in 1996.

Coley, Richard J., John Cradler, and Penelope K. Engel. *Computers and Classrooms: The Status of Technology in U.S. Schools*. Princeton, N.J.: Educational Testing Service, 1997. This document is available online in pdf (Adobe Portable Document) format at http://etsis1.ets.org/research/pic/compclass.html. Among the many findings in this report: "Research shows that helping teachers learn how to integrate technology into the curriculum is a critical factor for the successful implementation of technology applications in schools."

Cuban, Larry. *Teachers and Machines: The Classroom Use of Technology Since 1920*. N.Y.: Teacher's College Press, 1986. Cuban, a historian of education, outlines past educational technologies and their receptions in the classroom.

Dockterman, David A. *Great Teaching in the One Computer Classroom™*, 4th Edition. Watertown, MA: Tom Snyder Productions, 1997. Tom Snyder Productions (http://www.teachtsp.com) publishes highly regarded educational software. This book, recently updated to include consideration of the Internet's role in the classroom, is directed to teachers, as a very direct how-to manual *written by* a teacher.

Education Week. "Technology Counts: Schools and Reform in the Information Age." This supplement to the November 10, 1997 issue of *Education Week* includes articles and statistical summaries. The supplement was produced in collaboration with the Milken Exchange on Education Technology. The entire document is available at http://www.edweek.org/sreports/tc/.

Glennan, Thomas K., and Arthur Melmed. *Fostering the Use of Educational Technology: Elements of a National Strategy*. RAND, 1996. Posted at http://www.rand.org/publications/MR/MR682/contents.html and available as a printed RAND report.

Hargittai, Eszter. "The Pros and Cons of Implementing the Internet in the Classroom," a paper (research project) by a graduate student at New York University. Posted at http://pages.nyu.edu/~eh209/edu.

Oppenheimer, Todd. "The Computer Delusion." *The Atlantic Monthly*, July 1997, pp. 45-62. A skeptic's view. (This was reprinted in *The Sacramento Bee*'s "Forum" section, September 14, 1997.)

President's Committee of Advisors on Science and Technology, Panel on Educational Technology. *Report to the President on the Use of Technology to Strengthen K-12 Education in the United States*. March 1997. Posted at http://whitehouse.gov/WH/EOP/OSTP/NSTC/PCAST/k-12ed.htm. This document is sometimes simply referred to as "the PCAST report." Among the report's six strategic recommendations are "focus on learning *with* technology, not *about* technology," and "give special attention to professional development."

Rockman et al., and RPP International, with the Alameda County Office of Education. *Catching up with our Technology Future: Where We Are, Where We Need to Go*. A report, in three volumes, submitted to the California Department of Education, Office of Education Technology. The summary volume is dated June 1997; the Program-Level Findings volume and School-Level Findings volume are dated August 1997. This report, based on a 1995 survey and follow up data gathered in 1996 (and subsequent analysis) appears to be the most wide-ranging and current survey of educational technology in California K-12 schools.

Serim, Ferdi, and Melissa Koch. *Net Learning: Why Teachers Use the Internet.* Sebastapol, California: Songline Studios, Inc., and O'Reilly & Associates, 1996. Combines background and explanation with brief case studies of how schools, teachers, and students are using the Internet. The book comes with a CD-ROM disk that provides software and initial access to the Internet via GNN.

Stoll, Clifford. *Silicon Snake Oil: Second Thoughts on the Information Highway.* N.Y.: Doubleday Anchor Books edition, 1996 (originally published in 1995). Jaundiced view by a well known Internet security expert.

Umbach, Kenneth W. *The Internet: A California Policy Perspective.* Sacramento: California Research Bureau, 1997. Overview of what the Internet is and of a range of policy areas it affects, including a summary look at education and the Internet. A version is posted at http://www.library.ca.gov/html/statseg2.html

U.S. Congress. Office of Technology Assessment. *Teachers and Technology: Making the Connection.* OTA-EHR-616. Washington, D.C.: U.S. Government Printing Office, April 1995. The entire document (298 pages) is available at http://www.wws.princeton.edu/~ota/disk1/1995/9541.html.

Wresch, William. *A Teacher's Guide to the Information Highway.* Columbus, Ohio: Prentice Hall, 1997. One of the features of the book is a focus on curriculum, showing subject-by-subject how the Internet is being connected to classroom use. An appendix provides a listing, by subject, of "Web Sites for Schools" (educational materials on the Worldwide Web).

ENDNOTES

[1] Napa's New Technology High School (see http://www.nths.napa.ca.us/) and the New Haven Unified School District (Union City) (http://www.nhusd.k12.ca.us/NHUSD.html) are examples of advanced sites.

[2] Tom Snyder Productions offers a series of well regarded software for schools. Snyder was a teacher who became a software publisher.

[3] Mary Jo Lynch, Pamela Kramer, and Ann Weeks, *Public School Library Media Centers in 12 States: Report of the NCLIS/ALA Survey* (Washington, D.C.: U.S. National Commission on Libraries & Information Science, 1994), p. 3.

[4] The QED figures mentioned here and below were cited by Richard J. Coley, John Cradler, and Penelope K. Engel in *Computers and Classrooms: The Status of Technology in U.S. Schools* (Princeton, N.J.: Educational Testing Service, 1997).

[5] Rockman et al., and RPP International, with the Alameda County Office of Education, *Catching up with our Technology Future: Where We Are, Where We Need to Go.* This report, in three volumes, was submitted to the California Department of Education, Office of Education Technology. The summary volume is dated June 1997; the Program-Level Findings volume and School-Level Findings volume are dated August 1997. This report provides far more complex and extensive statistics than can be summarized here. The reader is referred to the summary volume for an overview. The student-computer ratio data are in the "School-Level Findings" volume, pp. 18-19.

[6] Rockman/RPP report, "School-Level Findings," p. 22.

[7] Rockman/RPP report, "School-Level Findings," p. 27.